ASSESSING GROUNDWATER QUALITY USING GEOSPATIAL TECHNOLOGY: A CASE STUDY OF SURAT DISTRICT, GUJARAT, INDIA

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Abstract: *The quality of water is a vital concern for mankind since it is directly linked to human health. Groundwater is a pivot because of its multiple uses for example, drinking, irrigation, and industrial, etc. Thus, the availability of water and also its quality are the dimensions essential for research. It has become necessary to determine the Groundwater Quality and for its determination, Water Quality Index (WQI) is an important index and Geospatial Technology is an effective tool. Hence, the present study was performed to determine the level of some physical and chemical properties of water in pre and post-monsoon seasons (2017-18) in Surat district, Gujarat, India. The objective of the paper is to assess the spatial pattern of groundwater quality with the use of Geospatial technology (GIS). Water quality was assessed using pH, turbidity, Total Dissolved Solid (TDS), calcium, magnesium, sulphate, chloride, fluoride, nitrate, alkalinity and total hardness parameters. Water Quality Index (WQI) is calculated to determine the quality of groundwater. The water quality index category of <25 WQI was noted in 20.44 percent area during pre-monsoon which decreased to 18.36 percent in post-monsoon. 72.66 percent area had 25-50 WQI. After the rains, this area decreased to 62.28 percent. <25 WQI was noted in 22.99 percent samples in pre-monsoon which reduced to 19.41 percent in the post-monsoon. The next category with 25-50 WQI was noted in 67.20 percent samples in pre-monsoon and 56.87 percent in the post-monsoon season. 50-75 WQI was noted in 9.80 percent samples in pre-monsoon which increased to 20.44 percent in the post-monsoon season. The range with 75-100 WQI was not detected in any of the samples in pre-monsoon and was observed in 3.26 percent samples after the rains.*

Key words: Spatial pattern, Water Quality Index, Variation Analysis, IDW, GIS.

Introduction

Groundwater is a prime natural resource and because of its multiple uses, it is considered to be an important component. The quality of groundwater depends upon many natural conditions like local climate, amount and intensity of rainfall, sub surface slope, geology, grain size of soil etc. The hydrochemistry of groundwater determines its quality and subsequently its utilization. One of the threats to groundwater quality is the rapid increase in urbanization and industrialization which might lead to its deterioration and become less suitable for drinking, irrigation, agricultural and industrial purposes. Eleven parameters considered for the present study are pH, turbidity, Total Dissolved Solid (TDS), calcium, magnesium, sulphate, chloride, fluoride, nitrate, alkalinity, and total hardness. Groundwater quality can be influenced directly and indirectly by microbiological processes which can transform both inorganic and organic constituents of groundwater through geochemical processes (Chapelle, 1993). Groundwater pollution occurs when used water is returned to the hydrological cycle (Basavarajappa and Manjunatha, 2015). Groundwater bodies are always less accessible than surface water bodies and technically difficult to derive a real picture. It contaminates mainly due to the rapid increase in population, industrialization, mining operations, application of fertilizers in agricultural fields and other manmade activities (Rao *et al.*, 2012). Industrialization is one of the most important phenomena which ignites the mechanism of development. Disposal of solid waste in open pits and depression, discharge of untreated liquid waste through open drains, and emission of toxic

gases into the atmosphere are a few common features prevalent in the industrial region and its vicinity. Groundwater gets contaminated in various ways such as excessive use of fertilizer in farming, seepage from effluent bearing discharged from industries, or human intervention. Once the groundwater gets contaminated, its quality cannot be restored by stopping the pollutant from the source in a short period (Sadashivaiah, 2008). The occurrence, distribution and movement and composition of groundwater are intricately linked to the structure and nature of the geological formations (Freeze & Cherry, 1979). The distribution of water in terms of quality and quantity varies from place to place and from one geological formation to another (Fetter, 1994).

Surat District is one of the fast industrializing regions of the State which has many industrial zones like Hazira in the west, Olpad in north-west and Surat city itself. These industries manufacture different types of chemicals, petrochemicals, polymers, fibres, etc. (GSIDS, 2016). The physico-chemical parameters study could help to determine the water quality. WQI calculation and Geographic Information System (GIS) has emerged as a powerful tool for storing, analysing and displaying spatial data and these data for decision making in several fields including environment, earth and engineering sciences, urban planning, agriculture, water resources etc. GIS is used as an effective tool for solution for water resources problem for assessing and mapping of groundwater quality. Thus, the present study is an important step towards it.

Objectives

Keeping in view the importance of quality of water the objective of the present paper is:

- To assess the groundwater quality.
- Analyze the spatio-temporal variation

Methodology

The secondary data of all physico-chemical parameters were collected from Gujarat Water Supply and Sewerage Board (GWSSB), Jal Bhavan, Surat. The temporal data of pre-monsoon and post-monsoon 2017-18 was taken into consideration. 582 groundwater samples were collected from wells, bores, and hand pumps spread over the Surat district. Eleven parameters have been considered for calculation of WQI such as: pH, turbidity, Total Dissolved Solid (TDS), calcium, magnesium, sulphate, chloride, fluoride, nitrate, alkalinity and total hardness for the water quality calculated by using Horton's method (1965) in original form, latter which modified by Brown et al., 1972 to determine the single value called Water Quality Index. WQI was inputted into ArcGIS 10.2 and Spatial Interpolation Method was applied and in this paper IDW (Inverse Distance Weighting) method was applied for the spatial pattern. For calculation of Water Quality Index, MS Excel 2013 was used and diagrams were prepared in Origin Pro 9.1. ArcGIS 10.2 was used for the representation of the map.

Spatial Interpolation Method

Interpolation method is the process of using point with known value or sample point to estimate at other unknown point. It can be used to predict unknown value for any geographic point data. In this paper IDW (Inverse Distance **W**eighting) method was applied for spatial pattern of the study area. This method gave a better visual illustration to understand the present conditions each of the parameters (Ghosh and Kanchan, 2014). The IDW interpolator assumes that each input point has a local influence that diminishes with distance. It weights the point closer to the processing cell greater than those further away. A specific number of point or all points within a specific radius can be used to determine the output value of each location.

Figure 01: Ground Water Sample Location

Water Quality Index

Water Quality Index (WQI) provides information about water quality in a single value. It is commonly used for the detection and evaluation of water pollution and may be defined as a reflection of the composite influence of different quality parameters on the overall quality of water (Horton, 1965). WQI indices are broadly classified into physico-chemical and biological indices. The former are based on the values of various physical and chemical parameters in water samples while biological indices are derived from biological information. Here, an attempt has been made to calculate the water quality index of the Surat district based on physico-chemical data. This research has adopted Horton's Method (1965) in its original form.

$$WQI = \frac{\sum q_n \cdot W_n}{\sum W_n}$$

Where, q_n = Quality rating of n^{th} water quality parameter, W_n = Unit weight of n^{th} water quality parameter.

Quality rating (q_n)

The quality rating (q_n) is calculated using the expression given in Equation:

$$q_n = \left[\frac{(V_n - V_{id})}{(S_n - V_{id})} \right] \times 100$$

Where, V_n = Estimated value of n^{th} water quality parameter at a given sample location.

V_{id} = Ideal value for n^{th} parameter in pure water. (V_{id} For pH = 7 and 0 for all other parameters).

S_n = Standard permissible value of n^{th} water quality parameter.

Unit weight (W_n)

The unit weight (W_n) is calculated using the expression given in Equation:

$$W_n = \frac{k}{S_n}$$

Where,

S_n = Standard permissible value of n^{th} water quality parameter. k = Constant of proportionality and it is calculated by using the

Expression given in Equation

$$k = \frac{1}{\sum \frac{1}{S_{n=1,2,\dots,n}}}$$

WQI and Status

Table 01: Ranges of WQI and Status and their Possible Uses as Per Horton's Method

Sr. No	WQI	Status	Possible usages
1	0-25	Excellent	Drinking, Irrigation, and Industrial
2	25-50	Good	Domestic, Irrigation and Industrial
3	50-75	Fair	Irrigation and Industrial
4	75-100	Poor	Irrigation

Source: Horton's Method (1965)

Standard values and unit weights of water quality for Physico-chemical parameters

Table 02: Standard Values of Water Quality Parameters and their Corresponding Ideal Values and Unit Weights

Name of Parameters	Permissible Standards	Vid=(1/sn)	K=[1/({1/Sn=1,2,n})]	Unit weight (k/Sn)
Ph	8.5	0.118	0.9700	0.1141
TDS	2000	0.001	0.9700	0.0005
Turbidity	5	0.200	0.9700	0.1940
T_hardness	600	0.002	0.9700	0.0016
Calcium	200	0.005	0.9700	0.0049
Mg	100	0.010	0.9700	0.0097
Chloride	1000	0.001	0.9700	0.0010
Sulphate	200	0.005	0.9700	0.0049
Nitrate	45	0.022	0.9700	0.0216
Fluoride	1.5	0.667	0.9700	0.6467
Alkalinity	600	0.002	0.9700	0.0016

Source: Bureau of Indian Standards, GOI

Figure 02: Flow Chart showing the Methodology

Study Area

Surat district lies between 20°30': 21°30'N and 72°35': 75°20'E with a total geographical area of 4,378 sq. km. (District Census Handbook Surat 2011). River Tapi is a major river that flows downstream towards the Gulf of Cambay. This district has many industrial zones like Hazira in the west, Olpad in north-west and Surat city. These industries manufacture different types of chemicals, petrochemicals, polymers, fibres, etc. (GSIDS, 2016).

Figure 03: Location Map

Geomorphology

Geographically, the district lies on the western coastal land of the Deccan peninsula. The distinct zones viz. hilly area is dominant in the north-eastern part, piedmont slope in east-central and this part shows a gentle slope towards the west. The topography is mainly plain with moderate to the deep cutting river valley and occasional hillocks. The alluvial plain is situated in the central part of the district and is characterized by flood plains of Tapi, Kim, and Purna Rivers. The coastal plain towards west merges into dry barren sandy shorelines (CGWB 2013).

Figure 04: Geological Map, Surat District

Geology

The geological formation of the district falls under the Deccan trap (Basalt rock), flood plain.

Hydrogeology

The hydro-geological framework of the area is essentially governed by geological setting, Tapi River, distribution of rainfall fall and facilities of circulation and movement of water through

interconnected primary and secondary porosity of the geological units forming the aquifers. The major aquifers in the district are formed by alluvium and Deccan trap basalt. The alluvium occurs in the western part of the district and along the streams whereas in eastern parts weathered and fractured basalt from aquifers.

RESULTS AND DISCUSSION

WQI of Pre-monsoon Groundwater Quality

The water quality of <25 was noted in 22.99 percent samples and it was largely observed in the north-eastern part of the study area. Small pockets were seen in north-western and as small patches in the south of the study area. This range of water quality is excellent for drinking.

Figure 05: Ground Water Quality, Surat District, 2017-18

This range was dominantly observed in the north-eastern part. This area has a Deccan trap where the rocks of very hard (igneous rock {basalt rock} with dykes). Chances of infiltration of water, reduces in hard rock largely due to porosity. Another large area is observed in the western part of the district. This area is an alluvial plain (sand and clay deposition) at the mouth of the Tapi River. The continuous flow affects the quality of the groundwater. It is continuously recharged by freshwater. WQI between 25 to 50 was noted in 67.20 percent samples spreading over 72.66 percent area. This range covered the entire region and is considered good for drinking, irrigation and industries. This area is both an alluvial plain as well as Deccan trap. The western part falls under the hilly region and the eastern part is plain. According to CGWB the groundwater flows from west to east directly in direction with the terrain. The range between 50 to 75 WQI is noted in 9.80 percent samples and is spread 6.88 percent area. This range was largely observed in the northern segment of the study area. The small isolated pockets were also noted in the western and southern half of the district. This range of water quality is fair and it's possible usage only for irrigation and industrial purposes (according to BIS for irrigation). The areas of northern pockets are nearer to industrial regions as well as Surat city (GSIDS, 2016). Another isolated pocket is observed in western side where water quality is not good, may be (i) because of the nearness to industrial region of Hazira (GSIDS, 2016), (ii) slope of the land and deposition of sediments brought by Tapi river (CGWB, 2013), and (iii) it's an alluvial region (sand and clay deposits) which helps water to get mixed with groundwater because of the large amount of porosity. No area is observed with >75 WQI.

WQI of Post-monsoon Groundwater Quality

A change in water quality was observed between the two seasons because of rainfall. <25 WQI was noted in 19.41 percent samples which were spread over 18.36 percent area dominantly in north-eastern, central-east, and as small isolated pockets in the western half. The geology of the eastern part plays an important role in this segment which predominantly has basalt rock (Figure 4) and at the same time there is an absence of industries (GSIDS, 2016). Another area where the water quality was excellent was on the western side. The downstream flow of the Tapi River from east to west helps to maintain the groundwater quality (CGWB, 2016). The next category (25 to 50 WQI) was noted in 56.87 percent samples covering 62.28 percent area. This category was spread over the entire study area and this quality of water is permissible for domestic, drinking, irrigation and industrial purposes. This range was absent in the north-eastern part. Between 50 to 75 WQI was noted in 20.34 percent samples covering 16.30 percent area. It was observed largely in northern and southern half and as small isolated pockets over the entire region except for in the north-east. >75 WQI was in 3.26 percent samples and they covered 3.04 percent area. It was observed in a large area in the north-west and as small isolated pockets in the southern half. This range of the WQI category is poor and can only be used for irrigation. In this area water quality is not good because of the tidal flat and nearness of industries.

Analysis of Spatio-temporal Variation

WQI (Area): The water quality index category of <25 WQI was noted 20.44 percent area during pre-monsoon which decreased to 18.36 percent in post-monsoon. As compared to pre-monsoon, 2.08 percent area has reduced in post-monsoon. The range of water quality is excellent for all purposes viz. drinking, domestic, irrigation and industries. In pre-monsoon, 72.66 percent area had 25-50 WQI. After the rains, this area percentage decreased to 62.28 percent with a decrease of 10.37 percent. The next category with 50-75 WQI was noted in 6.30 percent area in pre-monsoon and 16.30 percent in post-monsoon depicting an increase of 9.42 percent in area. In another category with >75 WQI, which is not acceptable for drinking and irrigation purposes, no area was noted in pre-monsoon and 3.04 percent in the post-monsoon season.

Figure 06: Water Quality Index (Area)

WQI (Samples): <25 WQI was noted in 22.99 percent samples in pre-monsoon which reduced to 19.41 percent in the post-monsoon. As compared to pre-monsoon, 3.57 percent of samples had reduced after the rains. The next category with 25-50 WQI was noted in 67.20 percent samples in pre-monsoon and 56.87 percent samples in post-monsoon. 10.37 percent of the samples were less in the post-monsoon season. 50-75 WQI was noted in 9.80 percent samples in pre-monsoon which increased to 20.44 percent in the post-monsoon season.

The range with 75-100 WQI was not detected in any of the samples in pre-monsoon and was observed in 3.26 percent samples after the rains. It was noted that in the lower WQI of water and dilution of different parameters is the probable reason for it. The percentage of samples decreased while this percentage increased after the rains. The infiltration besides, this district has a major river Tapi and minor rivers and their tributaries in which the flow of water increases and rate of infiltration also rises resulting into this pattern.

Figure 07: Water Quality Index (Samples)

Conclusion

The present study focused on the spatial pattern of groundwater quality in Surat District, Gujarat. Fluctuation was observed in each category of WQI in both seasons. The geological structure, urbanization and use of fertilizer in the agricultural field played a significant role in affecting water quality in the western part of the study area which is highly developed as compared to eastern part. It is very essential to sustain groundwater quality in poor quality zones in the district. For the improvement in groundwater quality, construction of concrete drainage lines, treating of industrial pollutant water before discharging into river, continuous monitoring of water quality, reframing the use of fertilizer limit for agricultural practices and reframing policy for discharging of industrial effluents are some of the means for improvising the water quality. In the overall study, the eastern part of the study area has good water quality which is suitable all purpose (viz. drinking, domestic, irrigation as well as industrial) because their geological structure is made up of basalt rock which helped in purifying water, absence of industries specifically chemical and urbanization This part is largely covered by forest and water bodies (UkaiDam).

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